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Sustainability Appraisal and Life Cycle Analysis of Strategic Waste Management Options

Report for the first review of North Wales Regional Waste Plan. Part 1

ea/br/bl/std/vr10thanni

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Executive Summary

The Welsh Assembly Government has appointed Environment Agency Wales to complete a life cycle analysis, best practicable environmental option assessment and sustainable waste management options appraisal to assist with the revision of the Regional Waste Plans in Wales. The first plans were published in 2003/04 to comply with TAN 21 and to ensure that land use planning in Wales accounts for the needs of waste management. A revision of these plans is required every three years, reflecting changes in the waste streams arising within the regions, changes in land use and developments in the treatment methods that may be adopted. The work described within this report provides quantitative environmental data for the considered waste management options, enabling direct comparison between each option.

The nineteen waste management options were developed and agreed by local authority members in work undertaken over the last 18 months. All options have high levels of recycling and composting, followed by a variety of treatment technologies to deal with the residual waste.

A life cycle analysis approach has been applied, using the Environment Agency WRATE software to provide an assessment of the environmental performance of the 19 options in accordance with waste quantities and compositions forecast for 2013.

A number of other criteria were also considered within the Sustainability Appraisal. There were 22 indicators in total, and they can be broadly grouped as environmental and health, socio-economic, waste management service delivery and public framework objectives. Generic data was used to score some of the indicators, WRATE outputs for others, and for some of the indicators a group of waste management professionals were asked to provide scores based on professional judgement. The Regional Waste Groups were asked to weight the indicators; that is to place an importance value on each of the criteria being scored. The totals for the weighted scores provide the final results, with the options with the higher scores being the more favoured options.

The results for the North Wales Regional Waste Group shows that waste management systems incorporating high levels of thermal treatment, or Mechanical Biological Treatment (MBT) pre-treatment followed by thermal treatment make up the top six options. The seventh option is autoclave/MHT followed by use of the Refuse Derived Fuel (RDF) as a feedstock to an existing off-site facility, for example a cement kiln.

As a number of options scored well in the appraisal, the conclusion from this sustainability assessment is that the highest scoring options should form a technical basis for further development of the Regional Waste Plan Review for North Wales. This allows for some flexibility in the option finally chosen, but gives broad guidelines as to the types of facilities that should be considered.

The results of these studies will be used to inform the North Wales Regional Waste Planning Group when they choose their preferred option for the Waste Plan Reviews, but will not be used in isolation. It should be noted that a number of other studies are also to be carried out, including Health Impact Assessment and Strategic Environmental Assessment, and a full public consultation process will be undertaken before a preferred option can be incorporated into the plan.

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1 Introduction

The drive towards more sustainable waste management methods is due, in part, to European waste legislation. This requires a shift from the disposal of wastes at landfill to a range of alternative treatment and disposal methods. European legislation also requires member states to develop an adequate network of waste facilities and to prepare waste management plans.

To implement this requirement, Technical Advice Note (TAN) 21, published by the Welsh Assembly Government (WAG) in November 2001, set out the framework for regional waste planning in Wales. TAN 21 required that Regional Waste Plans (RWP) were published for each of three regions of Wales within two years. The first plans were published in 2003-4.

The creation of the plans involved the development and appraisal of a range of waste management options. In line with the guidance in TAN 21 and Office of the Deputy Prime Minister (ODPM) guidance[1] on Planning for Sustainable Waste Management, these were subjected to Life Cycle Analysis (LCA) as part of a wider sustainability appraisal to determine the Best Practicable Environmental Option (BPEO) and the preferred Strategic Waste Management Option (SWMO).

BPEO assessments focus primarily on environmental indicators and impacts. In accord with the published guidance, the inclusion of additional sustainability indicators such as levels of employment and public involvement enables the options to be considered on environmental and practicability grounds to determine BPEO but also to incorporate socio-economic issues in the determination of SWMO[2].

Using the Environment Agency (EA) developed WISARD software, a life cycle analysis was conducted by SLR Consultants to determine the BPEO for the publication of the Regional Waste Plans in 2003. The analysis appraised six different waste management options and was used to generate a number of indicators to determine the BPEO. Additional sustainability indicators were evaluated using professional judgement and generic data to complete the SWMO assessment.

TAN 21 requires that the RWPs undergo a review every three years. As part of this review process, the range of waste management options for assessment has been expanded to include new and emerging waste technologies and refined to account for more current data on composition and arisings of waste.

The EA has completed the LCA for each of the new range of options for the RWP review. The LCA was conducted using a new tool designed to replace WISARD. The “Waste Resources Assessment Tool for the Environment” (WRATE) was developed by the EA, ERM and Golders Associates. Details of the WRATE software can be found in Appendix 1.

The appraisal of 19 waste management options has taken account of environmental, socio-economic and implementation issues through the use of 22 weighted indicators. The goal of the LCA study is to calculate 8 of the 22 indicators contributing towards the calculation of BPEO and SWMO from the options appraised. The indicators to be considered in the sustainability assessment, their derivation and whether their scores will contribute to determination of BPEO and SWMO or SWMO only are highlighted in table 45 of Part 2. The indicators incorporate weightings determined through consultation with the Regional Waste Group members.

The LCA and Sustainability Assessment will contribute directly to the RWP review. The assessment year is 2013 to which all waste streams have been forecast. The EA Waste Strategy team in Cardiff has conducted the study on behalf of the three regional waste planning groups.

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1 ‘Strategic Planning for Sustainable Waste Management: Guidance on Option Development and Appraisal’ (ODPM, 2002)

2 The concepts of BPEO and SWMO are discussed in Annex H of TAN 21, WAG (2002) and Chapter 3 of Wise About Waste: A National Waste Strategy for Wales , WAG (2002)

Options Development

The original LCA, incorporated into the RWPs, assessed six waste management options and used approximation modelling for a technology not included in WISARD. In light of the emergence of a range of new waste technologies and the enhanced capability of WRATE, a wider range of options have been assessed for the RWP review.

Waste stream arising has been projected to 2013 by the regional waste planning co-ordinators based on current understanding of waste growth and trends. These figures were agreed by each of the Regional Waste Groups for the following waste streams. The forecast for each stream can be found in Appendix 2 (table A8).

- Municipal Waste
- Construction and Demolition Waste
- Industrial and Commercial Waste
- Agricultural Waste
- Hazardous Waste

The options were discussed and developed at meetings of the three Regional Waste Group co-ordinators, EA, WAG and WLGA. It was agreed that, for each option apart from option 0, a baseline option included for comparative purposes only, the 2020 landfill directive target (below) would be met in 2013, the study year.

"to reduce the amount of biodegradable municipal waste landfilled to 35% of that produced in 1995"

Substantial levels of recycling/composting of municipal waste will be required through source segregation to satisfy WAG targets set for each Local Authority. These rates are defined within the option detail.

The source segregated recycling/composting rates relate primarily to the performance of local authorities in the management of municipal solid waste (MSW). WAG targets will need to be met for other waste streams i.e. recycling targets for construction and demolition (C&D) waste, landfill diversion for industrial and commercial (I&C) waste. The major impact on these streams will be the method of management of residuals and it is assumed that, where appropriate, all waste streams will use the facilities described in each option.

The Sustainability Assessment process of the Strategic Waste Management Options (SWMO) follows the guidance provided by OPDM (2002) 'Strategic Planning for Sustainable Waste Management: Guidance on Option Development and Appraisal' as recommended in 'Wise about Waste; The National Waste Strategy for Wales' (2002). The seven steps generally accepted as fulfilling the requirements of the SWMO process are as follows:

- Step 1 – Identify and agree objectives and indicators against which all SWMO will be measured. Objectives address environmental, socio-economic, operational issues and conformity with waste policy targets.
- Step 2 – Develop all viable SWMOs. Should cover all stages in waste management from collection through to treatment/disposal and to meet key objectives.
- Step 3 – Assess the performance of these options against the criteria identified within Step 1
- Step 4 – Value the performance scores for each option
- Step 5 – Apply weights to the sustainability indicators. This is because decision makers are likely to attach more importance to some indicators than others.
- Step 6 – Identify the preferred option, by multiplying the performance scores by the weights assigned in step 6 to the indicators.
- Step 7 – Sensitivity analysis & Option Refinement - analyse how sensitive the results are to variations in the assumptions made or the data used

By comparing how the options perform against the different indicators, we can assess the relative impacts of each of the options and determine the BPEO and SWMO in each RWG area. A summary of the options devised by the Regional Waste Planning Groups is presented overleaf. Chapter 2 outlines in more detail the modelling approach applied in the Life Cycle Analysis.

This report is divided into three sections. The main body of text can be found in part 1, results tables, graphs and figures are contained in part 2 with appendices, including a glossary of terms, in part 3.

Outline Options Description[3]

Option 0
'Do Nothing' strategy[4]
(This option is included for assessment purposes only – as a baseline to compare the other Options against). Front end levels of recycling and composting identical to the other options with no further treatment, projected on to waste tonnages arising in 2013

Option 1
A landfill-led strategy for residual waste
High recycling and composting levels followed by *low* levels of thermal treatment of residual waste using either:

- Pyrolysis (Option 1A), or
- Gasification (Option 1B), or
- Incineration with energy recovery (Option 1C)

All remaining residual waste would then be sent to landfill.
(Recycling / treatment levels are those required to achieve the 2020 (Biodegradable Municipal Waste (BMW) Landfill Directive target in 2013) where possible.

Option 2
An Energy from Waste-led strategy for residual waste
High recycling and composting levels with all remaining residual wastes, where possible, being treated by *high* levels of thermal treatment using either:

- Pyrolysis (Option 2A), or
- Gasification (Option 2B), or
- Incineration with energy recovery (Option 2C)
- Anaerobic digestion (Option 2D)

Any remaining residual waste would then be sent to landfill.
(Recycling/treatment levels are those required to achieve the 2020 BMW Landfill Directive target in 2013. Energy from Waste levels aim to minimise waste to landfill).

Option 3
An MBT/BMT-led strategy for residual waste
High recycling and composting levels, all remaining residual wastes being sent to MBT/BMT with the output recovered / disposed of using either:

- Pyrolysis (Option 3A), or
- Gasification (Option 3B), or
- Incineration with energy recovery (Option 3C), or
- Fuel to off-site energy use (Option 3D), or
- On-site Anaerobic digestion (Option 3E), or
- Landfill (Option 3F)

For Options 3A–3E, any remaining residual waste would then be sent to landfill.
(Recycling/treatment levels are the maximum possible – may exceed those required to achieve the 2020 BMW Landfill Directive target in 2013).

Option 4
An autoclave / MHT-led strategy for residual waste
High recycling and composting levels, all remaining residual wastes being sent to autoclave with the output recovered / disposed of using either:

- Pyrolysis (Option 4A), or
- Gasification (Option 4B), or
- Incineration with energy recovery (Option 4C), or
- Fuel to off-site energy use (Option 4D), or
- Landfill (Option 4E)

For Options 4A to 4E, any remaining residual waste would then be sent to landfill.

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[3] In all cases, the recycling/composting rate for municipal waste will exceed 50%. For option 1, the aspiration for the treatment of residual waste is to achieve the 2020 (Biodegradable Municipal Waste (BMW) Landfill Directive target in 2013, with all residual waste from other streams disposed at landfill. For options 2-4 all resiudal waste will be treated using the chosen technology type.

[4] This option has been amended for the life cycle analysis to represent a scenario whereby no alternative disposal or treatment options are developed and all residual waste is sent to landfill. Source separated recycling and composting rates are the same as in all other options

2 Strategic Waste Management Options for 2013

The principal aim of the sustainability appraisal and life cycle analysis was to determine the Best Practicable Environmental Option (BPEO) and Sustainable Waste Management Option (SWMO) for the management of mixed residual waste in North Wales. As discussed in chapter 1, 19 options were proposed for the North Wales Regional Waste Planning Group. During the assessment process, options 4A and 4B were ruled out. LCA Policy Advisors at the Environment Agency highlighted technical feasibility issues with these options. The assessment was completed on the remaining 17 options through the consideration of 22 environmental and sustainability indicators, which are detailed in table 45.

The waste management facilities considered were those that would receive household waste or similar fractions of industrial, commercial and agricultural wastes. The study also considered the management of construction and demolition wastes, but these were managed through dedicated facilities and did not alter between options.

It was acknowledged at the outset that a number of waste types would normally be managed through specific waste facilities other than those that have been considered for this assessment. It was essential then, to determine the likely composition of each of the considered waste streams and then make a set of assumptions regarding their likely management route.

The fractions of each waste stream that would require an alternative management route (e.g. hazardous chemical wastes or oils) were excluded from the life cycle analysis and sustainability appraisal and no detailed assessment of their management routes was considered. It is suggested that the determination of the preferred option for the treatment of mixed wastes is unlikely to influence or affect the choice of management route for waste oils for example. Table 4 lists all of the waste fractions that were excluded from the modelling exercise.

All Municipal Solid Waste (MSW) collected from the household or commercial premises were assumed to be managed through the facilities considered for this report. It was not possible to model the treatment of hazardous wastes collected separately at Civic Amenity sites. The type and arising of these wastes are shown in the first column of table 4. The modelled composition of MSW is shown in table 5 and figure 4.

As shown in table 4 and figure 3, the unmodelled waste is made up of 62% hazardous and 38% non-hazardous fractions. The greatest contributing waste stream is the industrial stream, making up 58.6% of the unmodelled waste. Four main fractions make up over half of the unmodelled wastes - food sludges (17%), hazardous oils and solvents (12%), hazardous chemical wastes (11%) and rejects from allumina metallurgy (11%). These fractions will not appear in the residual waste stream, as they require specialist treatment or disposal. Currently, much of the food wastes may be spread on land under an exemption from waste management licensing. In the future it is possible that anaerobic digestion will be a preferred treatment method for this type of waste.

The modelled compositions of industrial and commercial wastes are shown in table 6 and 7 and figures 5 and 6. It can be seen that three fractions account for over 80% of the modelled Industrial waste stream – organics (33%), wood (26.4%) and paper/card (211.4%). All other fractions account for less than 6% of the stream individually. Two waste streams – paper and card (37.5%) and organics (21.5%) - dominate the modelled commercial waste stream. All other fractions account for less than 9% if the stream individually.

The assumed composition of agricultural waste, shown in table 8 and figure 7 excluded the vast majority of organic agricultural wastes (manures, crop residues etc.) as it is expected that these will have an exempt or licensed management route on-farm or through other facilities not considered for this assessment. The modelled composition considers the inorganic fractions, such as plastic film and metals, which will require an external management route.

The composition of construction and demolition (C&D) waste, shown in Table 9 and Figure 8, was estimated to represent both the non-inert fractions within the stream and the inert fractions. This creates a requirement for significant levels of off-site recycling of plastic, metal and wood from C&D wastes. It was assumed that the data used for the SmithsGore survey (the baseline for forecasting the arising of construction and demolition wastes) did not account fully for the management of contaminated soils and other hazardous C&D wastes, therefore the forecast arising was for non-hazardous C&S waste only.

The key outcome of the sustainability appraisal process is to determine the preferred options for the treatment of residual waste. The diversion from landfill is modelled in two ways; firstly an assumption has been made regarding the rate of front-end separation of wastes for recycling and composting and secondly the method used to treat the residual fraction. As the rate of front-end separation is common to each option, in describing the aspiration of each option, it is only necessary to detail the method for residual treatment as the variable factor.

For all options, the diversion of MSW at the front end for recycling/composting is 50%. This reflects the proposed 2020 target in the current review of the English waste strategy[5]. To derive the required performance the composition of the waste was examined and potentially recyclable fractions were identified (these are shown in green in the composition table). Once identified, the capture rate of each fraction was adjusted until the required recycling rate was reached.

An 80.75% recycling rate was required for each of the recyclable fractions to create the desired overall rate of 50% for MSW. In other words, all of the fractions highlighted in green in table 5 would need to be recycled at a rate of 80.75% in order for the target of 50% recycling/composting to be met for the municipal waste stream as a whole. During the modelling process it was determined that inert municipal waste, described as “bricks, blocks and plaster” that is collected at CA sites is most suited to go to the C&D waste treatment facilities.

The 80.75% rate was then applied to the deemed recyclable fractions from each of the non-municipal streams[6]. This generated a source segregated recycling rate of 72.0% for modelled industrial waste, 58.1% for modelled commercial waste and 61.0% for modelled agricultural waste. For C&D waste, the 80.75% rate was applied to all recyclable fractions with the exception of the bricks, blocks and plaster fraction, which was modelled at a recycling rate of 95% in line with WAG targets. This combination of rates created an overall source segregated recycling rate of 83.5% for modelled construction and demolition waste[7].

The maintenance of an identical front-end performance across all options has ensured that the study identifies the differences between the residual treatment methods. The waste management systems modelled for each option are illustrated in figures 9-25. These show the tonnage of each waste stream delivered to each facility and the transport distance assumed for each step. For detailed modelling assumptions, see Appendix 2.

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[5] Review of England’s Waste Strategy - A Consultation Document, February 2006. DEFRA

[6] The fractions that were recycled or composted from each waste stream are highlighted in green in tables 5 – 9.

[7] The aggregate type materials within the C&D stream (Bricks, blocks and plaster) make up 69% of the C&D arising. This element has been recycled with a capture rate of 95% with all other recyclable elements captured at 80.75%.

Option 0 – 'Do Nothing' strategy

This option is included for assessment purposes only – as a baseline to compare the other Options against. The Regional Waste Planning Group does not consider it a valid, sustainable option, it will not meet all of the specified targets and it relies very heavily on landfilling to dispose of all residual waste.

The original idea was to maintain the current levels of recycling, composting, energy from waste and landfill, however, high recycling front end levels have been applied as in all the other options, but with no further treatment. This comparison shows the effect of the residual waste management technology options. For all non-hazardous and hazardous landfills, the modelled technology in WRATE is landfill with HDPE liner and HDPE cap. For inert landfill the assumption is for a clay liner and clay cap.

The waste flows and transport distances for option 0 are shown in figure 9, the subregional breakdown of option performance is in table 11 and the required throughput and infrastructure to deliver the modelled elements of waste are shown in table 28.

Option 1 – A landfill-led strategy for residual waste

The generic aspiration for options 1a-c is for high levels of source segregated recycling followed by low levels of thermal treatment of residual waste using pyrolysis, gasification or incineration with energy recovery. A "low" level of thermal treatment is interpreted to mean the amount of additional material required to be treated to increase the level of Biodegradable Municipal Waste (BMW) landfill diversion to meet 2020 landfill directive targets. All residual commercial, industrial and agricultural wastes will be disposed of to landfill.

1a – Pyrolysis

The management of residual waste for this option is through low level thermal treatment using the following pyrolysis technology from WRATE:

- 21252[8] Pyrolysis (MSW and RDF) WASTEGEN process

This is based on plant currently operating in Germany, which treats municipal and industrial waste, bulky waste and sewage sludge. The residual MSW in the model requires no pre-treatment for this technology. The tonnage treated will be sufficient to ensure that 2020 Landfill Directive Targets are met in 2013, with the remainder delivered direct to landfill. All non-hazardous bottom ash/char from thermal treatments is assumed to be recycled as aggregate substitute. All Air Pollution Control (APC) residues require disposal at hazardous landfill. Electricity production will offset against the marginal project energy mix[9] (see Appendix 2).

The waste flows and transport distances for this option are shown in figure 10, the subregional breakdown of option performance is in table 12 and the required throughput and infrastructure to deliver the modelled elements of waste are shown in table 29.

[8] These process ID numbers correspond with the reference numbers associated with each technology fact sheet in Appendix 3 of part 3. More detailed information on the WRATE technology can be found there.
[9] The marginal mix represents the mix of power sources used to account for fluctuations in demand. It is this mix that is offset when a facility in the model is used to produce electricity (such as electricity produced from the incineration of waste)

1b – Gasification

The management of residual waste for this option is through low level thermal treatment using the following pyrolysis technology from WRATE:

- 11268 Gasification (RDF only) ENERGOS process

The gasification process requires pre-treatment of the residual waste using a "dirty" materials recovery facility (MRF) to produce a Refuse Derived Fuel (RDF). For modelling purposes, the mechanical treatment element from a generic mechanical biological treatment (MBT) process in WRATE has been used to represent a dirty MRF. Information on the generic MBT processes in WRATE can be found in Appendix 3. Technology from WRATE data set to be applied:

- 11085 MBT pre-treatment GENERIC process

It is assumed the MRF is built on the same site as the gasification plant so no transport element will be required.

The MRF pre-treatment extracts additional metals (ferrous and non-ferrous) from the residual waste for recycling as well as producing a light refuse derived fuel (RDF) fraction for gasification and a residual stream, which requires a disposal route. It is assumed that all non-hazardous bottom ash/char from thermal treatments will be recycled as an aggregate substitute. All APC residues require disposal at hazardous landfill. The residual fraction from the MRF is disposed of to landfill.

This option requires sufficient tonnage of residual MSW to be put through the MRF and gasification process to enable 2020 Landfill Directive Targets to be met in 2013. Based on the forecast arising of MSW, the expected landfill allowance and the composition of residual waste after the front end recycling/composting, there is insufficient diversion of biodegradable waste to meet the 2020 target even when all residual MSW is sent to the facility. Electricity production will offset against the marginal project energy mix.

The waste flows and transport distances for this option are shown in figure 11, the subregional breakdown of option performance is in table 13 and the required throughput and infrastructure to deliver the modelled elements of waste are shown in table 30.

1c – Landfill and incineration with energy recovery

The management of residual waste for this option is through high level thermal treatment. To represent best practice in terms of heat recovery, the following incineration technology from WRATE has been modelled:

- 13041, Incinerator large, heat and power (COVENTRY) – for urban arisings
- 11262, Incinerator medium, heat and power (GRIMSBY) – for rural arisings

These two incineration technologies were selected as they both utilise heat as well as generating electricity and are the most representative technologies available in the model. The differing scales account for the different waste densities and throughputs in both urban and rural areas.

The tonnage treated will be sufficient to ensure that 2020 Landfill Directive Targets are met in 2013, with the remainder delivered direct to landfill. No pre-treatment is required for incineration with energy recovery technology. It is assumed that all non-hazardous bottom ash from thermal treatments will be recycled as an aggregate substitute. All APC residues require disposal at hazardous landfill.

The waste flows and transport distances for this option are shown in figure 12, the subregional breakdown of option performance is in table 14 and the required throughput and infrastructure to deliver the modelled elements of waste are shown in table 31.

Option 2 – Energy from Waste-led strategy for residual waste

For options 2 a-d, the generic aspiration is for high levels of recycling/composting followed by high levels of thermal or microbial treatment. A “high” level of thermal treatment is interpreted to mean that all residual waste, where feasible, will be treated using the treatment technology in that option.

2a – Pyrolysis

The management of residual waste for this option is through high level thermal treatment using the following pyrolysis technology from WRATE:

- 21252 Pyrolysis (MSW and RDF) WASTEGEN process

This is based on plant currently operating in Germany, which treats municipal and industrial waste, bulky waste and sewage sludge. The residual waste in the model requires no pre-treatment for this technology. All non-hazardous bottom ash/char from thermal treatments is assumed to be recycled as aggregate substitute. All APC residues require disposal at hazardous landfill. Electricity production will offset against the marginal project energy mix.

The waste flows and transport distances for this option are shown in figure 13, the subregional breakdown of option performance is in table 15 and the required throughput and infrastructure to deliver the modelled elements of waste are shown in table 32.

2b – Gasification

The management of residual waste for this option is through high level thermal treatment using the following pyrolysis technology from WRATE:

- 11268 Gasification (RDF only) ENERGOS process

The gasification process requires pre-treatment of the residual waste using a dirty MRF to produce an RDF. For modelling purposes, the mechanical treatment element from a generic MBT process in WRATE has been used to represent a dirty MRF. Information on the generic MBT processes in WRATE can be found in Appendix 3. Technology from WRATE data set to be applied:

- 11085 MBT pre-treatment GENERIC process

It is assumed the MRF is built on the same site as the gasification plant so no transport element will be required.

The MRF pre-treatment extracts additional metals (ferrous and non-ferrous) from the residual waste for recycling as well as producing a light RDF fraction for gasification and a residual stream, which requires a disposal route. It is assumed that all non-hazardous bottom ash/char from thermal treatments will be recycled as an aggregate substitute. All APC residues require disposal at hazardous landfill. The residual fraction from the MRF is disposed of to landfill.

Based on the forecast arising of MSW, the expected landfill allowance and the composition of residual waste following front end recycling/composting, there is insufficient diversion of biodegradable waste to meet the 2020 target even when all residual MSW is sent to the facility. . Electricity production will offset against the marginal project energy mix.

The waste flows and transport distances for this option are shown in figure 14, the subregional breakdown of option performance is in table 16 and the required throughput and infrastructure to deliver the modelled elements of waste are shown in table 33.

2c – Incineration with energy recovery

The management of residual waste for this option is through high level thermal treatment. To represent best practice in terms of heat recovery, the following incineration technology from WRATE has been modelled:

- 13041, Incinerator large, heat and power (COVENTRY) – for urban arisings
- 11262, Incinerator medium, heat and power (GRIMSBY) – for rural arisings

These two incineration technologies were selected as they both utilise heat as well as generating electricity and are the most representative technologies available in the model. The differing scales account for the different waste densities and throughputs in both urban and rural areas.

In determination of required capacity, the urban and rural capacities for incineration as detailed in table 1 are still assumed.

No pre-treatment is required for incineration with energy recovery technology. It is assumed that all non-hazardous bottom ash from thermal treatments will be recycled as an aggregate substitute. All APC residues require disposal at hazardous landfill. Electricity production will offset against the marginal project energy mix.

The waste flows and transport distances for this option are shown in figure 15, the subregional breakdown of option performance is in table 17 and the required throughput and infrastructure to deliver the modelled elements of waste are shown in table 34.

2d – Anaerobic digestion

The management of residual waste for this option is through high levels of biological treatment of residual waste using Anaerobic Digestion (AD). AD facilities alone only treat source separated wastes. The anaerobic digestion of mixed waste is modelled as part of an MBT process. The following technology is applied in the model:

- 20216 MBT AD & low grade compost GLOBAL RENEWABLES process

This Is based on the Global Renewables UR-3R MBT plant. It is assumed that the MBT/AD bio-stabilised outputs of the organic element of mixed waste would be disposed of to landfill[10]. The MBT pre-treatment will move the recycling performance beyond the 50% achieved through source segregation. Biogas production from the AD process will offset against electricity production in accord with the marginal project energy mix.

The waste flows and transport distances for this option are shown in figure 16, the subregional breakdown of option performance is in table 18 and the required throughput and infrastructure to deliver the modelled elements of waste are shown in table 35.

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[10] Current Agency guidance (http://www.environment-agency.gov.uk/commondata/acrobat/mbt_output_guidance_1149762.pdf) on the regulation of outputs of MBT where the feedstock is mixed MSW (or similar) is that the organic outputs would not be suitable for agricultural use. For modelling purposes, as all MBT options will receive mixed MSW, the impacts of landfilling this fraction will be included based on this guidance, as it would be unrealistic to include the offset benefits of compost production where this is unlikely to be the case.

Option 3 – MBT/BMT-led strategy for residual waste

For options 3 a-f, the generic aspiration is for high recycling/composting followed by high levels of MBT (Mechanical and Biological Treatment). A "high" level of MBT is interpreted to mean that all residual waste, where feasible, will be treated using the treatment technology in that option.

Biological and Mechanical Treatment (BMT) is a similar process to MBT, but the biological stage precedes the mechanical stage whereas in MBT the mechanical stage is first, followed by the biological stage.

3a – MBT followed by pyrolysis

The management of residual waste for this option is using MBT with the resultant RDF treated at a pyrolysis plant. The MBT process is based on the following two Generic processes from WRATE:

- 11089 MBT crushing and metals GENERIC process
- 11088 MBT dry stabilisation & RDF GENERIC process

These processes when combined represent a generic MBT facility that receives mixed waste and, using a two phase MBT process, mechanically crushes and sorts the waste and biologically treats the waste to bio-stabilise the residual fraction and create a high calorific RDF for thermal treatment. The RDF feedstock is then thermally treated using pyrolysis.

- 21252 Pyrolysis (MSW and RDF) WASTEGEN process

It is assumed the MBT plant is built on the same site as the pyrolysis plant so no transport element will be required.

The MBT pre-treatment extracts additional metals (ferrous and non-ferrous) from the residual waste for recycling. The second stage of the process produces a light RDF fraction for pyrolysis and a bio-stabilised residual stream, which requires a disposal route.

It is assumed that all non-hazardous bottom ash/char from thermal treatments will be recycled as an aggregate substitute. All APC residues require disposal at hazardous landfill. The stabilised residual fraction from MBT is disposed of to landfill.

The waste flows and transport distances for this option are shown in figure 17, the subregional breakdown of option performance is in table 19 and the required throughput and infrastructure to deliver the modelled elements of waste are shown in table 36.

3b – MBT followed by gasification

As with option 3a, the same two generic MBT processes are used. The RDF created is then treated using the following gasification technology from WRATE:

- 11268 Gasification (RDF only) ENERGOS process

It is assumed the MBT plant is co-located with the gasification plant so no transport element is required.

The MBT pre-treatment extracts additional metals (ferrous and non-ferrous) from the residual waste for recycling. The second stage of the process produces a light RDF fraction for gasification and a bio-stabilised residual stream, which requires a disposal route.

It is assumed that all non-hazardous bottom ash/char from thermal treatments will be recycled as an aggregate substitute. All APC residues require disposal at hazardous landfill. The stabilised residual fraction from MBT is disposed of to landfill. A landfill with HDPE liner and HDPE cap has been modelled.

The waste flows and transport distances for this option are shown in figure 18, the subregional breakdown of option performance is in table 20 and the required throughput and infrastructure to deliver the modelled elements of waste are shown in table 37.

3c – MBT followed by incineration with energy recovery

As with option 3a, the same two generic MBT processes are used. The RDF created is thermally treated using the following incineration technologies from WRATE:

- 13041, Incinerator large, heat and power (COVENTRY) – for urban arisings
- 11262, Incinerator medium, heat and power (GRIMSBY) – for rural arisings

These two incineration technologies were selected as they both utilise heat as well as generating electricity and are the most representative technologies available in the model. The differing scales account for the different waste densities and throughputs in both urban and rural areas.

As agreed capacity of the incineration facility for urban locations is large relative to the expected output from MBT, one MBT plant is assumed to be co-located at the incineration plant with the remaining MBT facilities evenly distributed throughout the area at a ratio of 1 co-located to 3 satellite.

The MBT pre-treatment extracts additional metals (ferrous and non-ferrous) from the residual waste for recycling. The second stage of the process produces a light RDF fraction for incineration and a bio-stabilised residual stream, which requires a disposal route.

It is assumed that all non-hazardous bottom ash from incineration will be recycled as an aggregate substitute. All APC residues require disposal at hazardous landfill. The stabilised residual fraction from MBT is disposed of to landfill. A landfill with HDPE liner and HDPE cap has been modelled.

The waste flows and transport distances for this option are shown in figure 19, the subregional breakdown of option performance is in table 21 and the required throughput and infrastructure to deliver the modelled elements of waste are shown in table 38.

3d – MBT followed by fuel to offsite energy use

As with option 3a, the same two generic MBT processes are used. The RDF created would then be transported off-site for co-firing in a cement kiln:

- 21274 RDF combustion in cement kiln

To determine trip distances for modelling purposes, the waste will be modelled as being transported to an existing cement kiln in North Wales. The offset is the burning of coal as a fuel in the cement kiln. A landfill with HDPE liner and HDPE cap has been modelled.

The waste flows and transport distances for this option are shown in figure 20, the subregional breakdown of option performance is in table 22 and the required throughput and infrastructure to deliver the modelled elements of waste are shown in table 39.

3e – MBT followed by anaerobic digestion

The management of residual waste for this option is through MBT including anaerobic digestion. The process is based on the following two stage generic MBT process from WRATE:

- 11085 MBT Pre-treatment GENERIC process
- 12087 MBT AD for stabilite GENERIC process

This two stage MBT process represents firstly a mechanical pre-treatment, which separates ferrous and non-ferrous metal for recycling, a light fraction that could be used as RDF and an organic rich fraction that requires biological treatment. In this scenario the light RDF fraction is landfilled as no thermal technology was proposed for the option. The metals are sent for recycling and the organic rich fraction is then sent to the second stage for anaerobic digestion.

Following AD, it is assumed that the bio-stabilised digestate, along with any rejects from the process, are disposed of to landfill. A landfill with HDPE liner and HDPE cap has been modelled. Biogas production from the AD process is offset against electricity production in accord with the marginal project energy mix.

The waste flows and transport distances for this option are shown in figure 21, the subregional breakdown of option performance is in table 23 and the required throughput and infrastructure to deliver the modelled elements of waste are shown in table 40.

3f – MBT followed by Landfill

The management of residual waste for this option is through MBT including aerobic composting. The process is based on the following two stage generic MBT process from WRATE:

- 11085 MBT Pre-treatment GENERIC process
- 12086 MBT composting for stabilite GENERIC process

This two stage MBT process represents firstly a mechanical pre-treatment, which separates ferrous and non-ferrous metal for recycling, a light fraction that could be used as RDF and an organic rich fraction that requires biological treatment. In this scenario the light RDF fraction is landfilled as there is no provision for thermal treatments within the option, the metals are sent for recycling and the bio fraction is then sent to the second stage for composting. This process stabilises the organic rich fraction and reduces its biodegradability prior to disposal.

It is assumed that the composted waste, along with any rejects from the process, is disposed of to landfill. A landfill with HDPE liner and HDPE cap has been modelled.

The waste flows and transport distances for this option are shown in figure 22, the subregional breakdown of option performance is in table 24 and the required throughput and infrastructure to deliver the modelled elements of waste are shown in table 41.

Option 4 – An autoclave/Mechanical Heat Treatment -led strategy for residual waste

For options 4 a-e, the generic aspiration is for high recycling/composting followed by high levels of treatment using an autoclave (or mechanical heat treatment – MHT). A "high" level of MHT is interpreted to mean that all residual waste, where feasible, will be treated using the treatment technology in that option.

The autoclave treatment technology available in the WRATE model is based upon data supplied by Estech, that were the only technology provider within the autoclave/MHT sector able to supply data of sufficient quality to include in the WRATE software. The technology is not currently used in the UK at a commercial scale for the treatment of MSW. The reference facility, and the associated data held in WRATE, is a pilot plant and the performance has been scaled up to represent a full scale plant. As the technology is in development, a full set of operational data is not currently available. This is an emerging technology and a number of providers are developing plants to treat MSW. It may be that future releases of WRATE will include a more complete picture of the technology's performance by including several different reference plants.

It is the opinion of the LCA policy advisors at EA head office that there is insufficient evidence that autoclave fibre can be used as an RDF for pyrolysis or gasification and thus options 4a and 4b have been excluded from the assessment.

The viability of the output fibre as an RDF to be used as a feedstock for incineration with energy recovery or cement kiln is uncertain as are the markets for the recovered recyclate for a technology that is unproven on a commercial scale. A precautionary approach has thus been adopted to both the recyclate extracted and the fibre produced. 50% of the fibre produced will be thermally treated in options 4c and 4d with the remainder disposed of to landfill and in each autoclave option, 50% of the recovered plastic recyclate will be landfilled. The recovered glass will only be used as an aggregate substitute as it is expected levels of grit and treated glass will preclude it from being recycled into glass packaging.

This approach will have altered the performance of this option. When a commercial scale operational plant is able to provide evidence that the outputs are of sufficient quality to secure their desired markets, this option could be re-evaluated.

4a – Autoclave/MHT followed by pyrolysis

Scenario excluded

4b – Autoclave/MHT followed by gasification

Scenario excluded

4c – Autoclave/MHT followed by incineration with energy recovery

The treatment technology used for residual waste in this option is autoclave. The process is based on the following process from WRATE:

- 21227 Autoclave (Mechanical Heat Treatment)

The autoclave treats the mixed waste using high pressure steam to treat the waste producing a clean fibrous material that can be used in the manufacture of fibreboard. Alternatively, by adding a drying stage, it may be suitable as a feedstock for either incineration with energy recovery or as a feedstock for a cement kiln. The process also extracts additional recyclate and a reject fraction that requires landfill disposal. 50% of the fibre has been delivered to the following two energy from waste facilities:

- 13041, Incinerator large, heat and power (COVENTRY) – for urban arisings
- 11262, Incinerator medium, heat and power (GRIMSBY) – for rural arisings

These two incineration technologies were selected as they both utilise heat as well as generating electricity and are the most representative technologies available in the model. The differing scales account for the different waste densities and throughputs in both urban and rural areas.

The remaining fibre has been sent to landfill. 50% of the plastic recyclate extracted has been recycled and the remaining material has been disposed of to landfill. A landfill with HDPE liner and HDPE cap has been modelled.

The waste flows and transport distances for this option are shown in figure 23, the subregional breakdown of option performance is in table 25 and the required throughput and infrastructure to deliver the modelled elements of waste are shown in table 42.

4d – Autoclave/MHT followed by fuel to offsite energy use

This scenario is the same as 4c except that 50% of the autoclave fibre is delivered to a cement kiln rather than an incinerator with energy recovery. The cement kiln process in WRATE is:

- 21274 RDF combustion in cement kiln

To determine trip distances for modelling purposes, the waste will be modelled as being transported to an existing cement kiln in North Wales. The offset is the burning of coal as a fuel in the cement kiln.

The remaining fibre has been sent to landfill. 50% of the plastic recyclate extracted has been recycled and the remaining material has been disposed of to landfill. A landfill with HDPE liner and HDPE cap has been modelled.

The waste flows and transport distances for this option are shown in figure 24, the subregional breakdown of option performance is in table 26 and the required throughput and infrastructure to deliver the modelled elements of waste are shown in table 43.

4e – Autoclave/MHT followed by Landfill

This option is the same as 4c except that 100% of the fibre produced is disposed of to landfill. As with the other viable autoclave options a precautionary approach has been applied with respect to the availability of markets for the recyclable material extracted by the autoclave process with 50% of the plastic being sent to landfill. A landfill with HDPE liner and HDPE cap has been modelled.

- 21227 Autoclave (Mechanical Heat Treatment)

The waste flows and transport distances for this option are shown in figure 25, the subregional breakdown of option performance is in table 27 and the required throughput and infrastructure to deliver the modelled elements of waste are shown in table 44.

3 Infrastructure Requirements

Existing waste management facilities

Table 2 illustrates the current licensed non-landfill waste management infrastructure in North Wales. The data in the first part of the table summarises the maximum licensed capacity of facilities that held either a PPC permit or Waste Management Licence at the 31st March 2006. The capacity is the legislative maximum throughput allowed under the terms of the license or permit. In reality there may be other limiting factors that restrict the site from operating up to it's licensed maximum.

It can be seen that the existing capacity of residual waste treatment technologies as proposed in the options is very limited. There is an urgent need to commission new infrastructure in order to meet 2013 targets for landfill diversion whichever waste management option is chosen. There is no merchant capacity for hazardous landfill in the North Wales region or Wales as a whole.

It should be noted that the range of facility types listed in table 2 is beyond those that have been considered for modelled waste in the life cycle assessment. Facilities such as chemical treatment plants are specialist and are likely to deal with either hazardous wastes or other process wastes that are outside the scope of the modelling and appraisal process.

Table 3 and figure 54 show the current landfill void available in North Wales. The data presented is the best case scenario from data collected in 2006 by the Environment Agency. The available void data assumes that the site that is going through the permitting process receives a permit. The table also includes estimations of how much landfill void will be used between now and 2012/13 and beyond to 2019/2020.

This estimation is based upon the continuation of current landfilling rates from the present until 2010/2011, then on a linear reduction of landfill from then to the expected tonnage landfilled to deliver each option. Also included in the filling rate is known imports of waste from outside Wales to North Wales landfills based on a steady import at 2005 rates[11].

It should be noted that the current rates of landfill have been derived from 2005 waste site returns and include:

- Waste that is disposed of to landfill in Wales where the origin of the waste is recorded as a local authority area in North Wales;
- Waste disposed of in landfill sites in North Wales where the origin is outside of Wales, uncodeable or just recorded as Wales.

The current rate of landfill excludes:

- Any waste that may have been produced in the area and disposed of into landfill outside of Wales.

This rate reflects self-sufficiency for North Wales whilst acknowledging that other regions may not achieve self-sufficiency.

The fill rate is based on an assumed density of 1 t/m^3 for all wastes. It is estimated that some void will still be available in 2012/13 for all options based on this set of assumptions, but the rate at which landfill is depleted beyond the study year varies significantly between the options. Option 2C preserves the most landfill void with an estimated 3,863,330m^3 remaining in 2012/13 and a subsequent annual requirement of 412,026 tonnes input per annum. Option 1C (which landfills the maximum possible MSW to still meet the 2020 Landfill Allowance target for BMW in 2013) leaves only 3,290,350m^3 with a further annual requirement of 794,012 tonnes input per annum.

[11] This is the modelled tonnage plus an estimated 144,357 tonnes per annum from outside of Wales

Required Infrastructure

Tables 28 to 44 show the potentially required waste management capacity for each of the options. The tables show this required infrastructure by capacity for annual tonnage throughput and number of facilities that would be required based on the agreed capacities indicated in table 1. This is broken down to local authority level and split by municipal, commercial, industrial, construction and demolition and agricultural waste streams. The required facility types for all options are assumed to be:

- Civic Amenity sites
- Household, Industrial and Commercial (HIC) waste transfer stations
- Construction and Demolition (C&D) waste transfer stations
- In-vessel composting sites
- Open windrow composting sites
- C&D exempt sites
- C&D recycling sites
- Non-hazardous landfill
- Hazardous landfill
- Inert landfill

For each option there will also be the relevant waste treatment technology such as pyrolysis plant, gasification plant, incineration plant, anaerobic digestion plant, MBT, MRF and autoclave plant.

Unmodelled Waste

It is important to note that tables 28 to 44 show the required infrastructure for the modelled wastes only. The amount of modelled and unmodelled wastes is represented in figures 1 and 2. The estimated composition of unmodelled waste is shown in Table 4 and Figure 3.

Unmodelled Hazardous Waste

Hazardous waste has not been specifically modelled within the WRATE assessment as the life cycle analysis applies to non-hazardous waste only. The North Wales Regional Waste Planning Group has forecast an arising of 79,138 tonnes of hazardous waste for 2013. A substantial part of this has been identified from the data used to create table 4 from the compositions of each of the waste streams. It is assumed that a lot of the hazardous waste is actually double counted in the forecasting exercise. Hazardous industrial wastes, for example, are included in the baseline data used to forecast the arising of industrial waste but also appear in the forecast arising of hazardous waste.

As mentioned in chapter 2, it is assumed that the baseline used to forecast the C&D arisings did not account for hazardous C&D arisings. Therefore the amount of the hazardous waste that cannot be attributed to the specific hazardous wastes in table 4 can be assumed to arise from the C&D sector.

This will require additional treatment or landfill capacity to that shown in tables 28-44. There is expected to be a large amount of hazardous chemical wastes and hazardous oils and solvents from both the industrial and commercial waste streams that are likely to be treated. The main arising of unmodelled hazardous waste from the Municipal waste stream are batteries and Waste Electrical and Electronic Equipment (WEEE) / End of Life vehicles (ELV).

Unmodelled Non-hazardous waste

As seen in Table 4 and Figure 3, much of the unmodelled waste is food waste from the Industrial waste stream, which is likely to be landspread or anaerobically digested. Chemical sludges, industrial sludges and septic tank sludges are likely to be landspread or treated.

These unmodelled wastes, hazardous and non-hazardous, will need to be planned for in addition to the modelled wastes from the life cycle analysis and sustainability appraisal.

4 Sustainability Assessment Methodology

The Sustainability Assessment of the options, as previously mentioned, follows the guidance provided by ODPM (2002) ‘Strategic Planning for Sustainable Waste Management: Guidance on Option Development and Appraisal’. The guidance sets out a methodology to appraise strategic waste management options (SWMO) that takes account of environmental, socio-economic and implementation issues. The Guidance recommends:

Identifying and agreeing Objectives and Indicators – In this assessment we have used the 22 indicators used in the preparation of the first regional waste plan (see list and description in Table 45). The Local Authority Members Steering Group reviewed these and it was agreed that the indicators were relevant for the Regional Waste Plan Review. The suite of indicators includes the additional indicator (added by the South East regional waste group) for dioxin emissions.

Identifying performance scores for the Sustainability Indicators - The performance scores for each of the indicators for the different options are generated using three methods:

- Quantitative Assessment Tool – WRATE Life Cycle Assessment (LCA) software tool (see Appendix 1 for detail about the software and appendix 6 for a summary of the indicators used in this report)
- Generic Data – scores are generated based on data available such as land take, number of jobs created etc.
- Professional Judgement (see Appendix 6 for more detail)

Table 45 details which method is used to generate performance scores for the different sustainability indicators. Each indicator is numbered in the format 1(i) where the number corresponds to the overall sustainability objective and roman numerals represent the specific indicator. This notation is used where the indicator results are tabulated in tables 63-67.

5 Sustainability Objectives and Indicators Information

This section gives information on the Sustainability Objectives that have been used in the Sustainability Appraisal.

Environmental & Health Objectives

1. To Ensure Prudent Use of Land and Other Resources

A key sustainable development objective is to use finite natural resources (such as fossil fuels and land) more efficiently. The rate of consumption of resources should not reduce their availability for future generations. For example, reusing or recycling waste reduces the environmental pollution and degradation caused by extraction, use and disposal of natural resources.

The choice of waste management option can have a significant influence on the consumption of finite natural resources. For example, an option involving reuse and recovery of materials should result in a reduction in the consumption of primary raw materials. An option involving recovery of energy from waste should result in a reduction in the use of fossil fuels. Land is also a finite resource, and some waste management options are more ‘land hungry’ than others.

2. To Reduce Greenhouse Gas Emissions

Global climate change is widely recognised as one of the greatest environmental challenges facing the world today. The clear message from the scientific community is that climate change is due, at least in part, to the increasing concentrations of greenhouse gases in the atmosphere.

A number of waste management operations give rise directly or indirectly to emissions of greenhouse gases. The main sources of CO2 emissions include: vehicles used to collect and transport waste, energy used to power waste facilities, composting operations, combustion of waste, and flaring of landfill gas. The decomposition of waste in landfill sites also gives rise to methane (CH4), which is around 20 times more potent a greenhouse gas than CO2.

3. To Minimise Adverse Impacts on Air Quality and Public Health

A key objective is to control air pollution in order to reduce the risks to human health, natural environment and quality of life. Pollutants of most concern to the Assembly Government are Nitrogen Dioxide, Sulphur Dioxide, Carbon Monoxide, particles (PM10) and Ozone.

Man-made emissions of substances containing chlorine and bromine can have consequential effects on both the environment and health. In respect of Waste Management, probably the main generator of ozone depleting substances is landfill.

Small particles of dust (PM10) are injurious to public health. However, it is the soiling of property that is the most common cause of complaint. Waste management processes potentially give rise to dust, particularly where mechanical operations and storage of waste takes place in the open. Vehicle movements can also generate significant dust.

Odour is a common cause of public concern in relation to waste management and like dust, odours can be particularly acute where mechanical operations and storage of waste take place in the open.

Dioxin emissions are a matter of public concern in relation to certain waste management technologies. These substances are very tightly controlled through regulation but the indicator is included because there is public concern about this particular aspect.

4. To Conserve Landscapes and Townscapes

Landscapes and townscapes result from the interactions between the physical, biological and social components of our environment and have strong economic, social and community value. The Assembly Government is keen to improve the quality of both countryside as a whole and of urban environments and increased attention is also being placed on the importance of perceptual characteristics such as tranquillity, wildness and dark night skies.

All waste management options involve development components such as buildings, processing plant, access roads, lighting/signage, storage mounds and perimeter bunds. These can have landscape impacts and visual impacts. Concern is likely to be greatest where options involve emissions stacks, large enclosed facilities or significant storage/disposal of waste above ground level.

5. To Protect Local Amenity

Living and working environments make an important contribution to 'quality of life'. In addition to attractive settings, access to green spaces, and community safety, low levels of noise and litter are important considerations. Noise and the existence of litter can cause annoyance and stress, and the number of noise complaints is increasing. Vermin is a subject that is commonly associated to waste storage in the open, and in fact can be attracted also to street litter.

All waste management options generate noise and potentially litter, as they involve the storage, treatment and transport of waste. Litter and vermin are most likely to be of concern where the waste is stored or processed/deposited in the open. Noise is most likely to be of concern in relation to sites that operate outside standard working hours, or use particularly noisy machinery.

6. To Minimise Adverse Effects on Water Quality

Water is essential for life, provides important habitats for plants and animals, and plays an important role in the economy. A key sustainable development objective is to sustain and improve surface and groundwater quality and the aquatic environment. Eutrophication is caused by excess nutrients (nitrate and phosphate) getting into the aquatic environment causing increased algal growth and potentially toxic algal blooms.

All waste management options have potential impacts on water as they involve the storage of waste, transport of waste, and the operation of plant and vehicles. These risks include:

- The storage of waste - run off from rain and dust suppression sprays, leaching of contaminants
- The transport of waste - run off from the delivery and tipping of materials, wheel washing)
- The operation of plant and vehicles - potential pollution from oil and solvents including the risk of accidental spillage

However, some waste management options present a greater risk to water quality than others, for example:

- Composting: Water is generated as part of the process and the compost has to be turned and wetted; The liquor generated from this process may contain heavy metals and other contaminants.
- Anaerobic digestion: The process creates digestate liquor, which may contain high levels of heavy metals and other contaminants.
- Incineration: Cooling and cleaning water may contain high levels of contaminants, whilst the storage and disposal of ash and air pollution control residues poses a further threat to water quality.

- Landfill/landraising: The risk of pollution depends on the characteristics of the wastes, the standard of site engineering, the underlying geology and the proximity of water courses and abstraction points. The Environment Agency's advice is that, however well engineered a landfill site, there is a risk of leachate release to the water environment.

Socio-Economic Objectives

7. To Minimise Local Transport Impacts

An efficient transport system is needed to support a strong and prosperous economy and to maintain and improve people's quality of life. Congestion and unreliability of journeys add to the costs of business, and undermines competitiveness. Major roads can cause 'severance' when people become separated from parts of the community and other people. Heavy levels of traffic also damages towns and cities and harms the countryside.

All waste management options have transport impacts as they involve some degree of off-site movement of waste. The scale of impacts will be influenced by factors such as vehicle size, frequency of vehicle movements, road/pavement width and traffic speeds. The proportion of motorway and non-motorway transport will be region specific according to the available transport network.

8. To Provide Employment Opportunities

A high employment rate is one of the key objectives of sustainable development. Development of new waste management facilities will create temporary construction employment, which may be available to local people, and their long-term operation will create jobs, the nature of which will depend on the facility.

9. To Provide Opportunities for Public Involvement and Education

Public participation is at the heart of sustainable development. Recent surveys in the North West of England suggest that the public is keen to participate in more sustainable waste management practices. In this context it is important for the Assembly Government, nationally and regionally to 'send the right signals' to the public in order to encourage changes in behaviour and lifestyles.

Waste Management Service Delivery Objectives

10. To Minimise the Costs of Waste Management

Although not strictly a sustainability objective, costs are clearly a key concern of local authorities and waste contractors. There are widely varying estimates of waste collection and waste treatment/disposal costs, of which the ETSU/DTI publication 'An Introduction to Household Waste Management' (1998), gives useful cost information for a range of facilities. Also information is available from the waste technologies database managed by the Environment Agency[12] and available through our website.

[12] www.environment-agency.gov.uk/wtd

11. To Ensure Reliability of Delivery

Although a waste management option may perform well against a range of indicators, it may not be possible to implement the option due to practical constraints. Such constraints may include:

- Availability of financial resources
- Technological issues, related to the availability of the appropriate plant and machinery
- Difficulties in obtaining planning consents

Public Framework Objectives

12. To Conform with Waste Policy

The Welsh Assembly Government actively promotes the waste hierarchy, including (in the following order of preference) waste reduction, re-use, recycling and composting, energy recovery, with disposal as a last resort. The Government also wishes to see waste managed in line with the proximity principle which states that waste should generally be disposed of as near to its source as possible. This is in part to ensure that waste problems are not simply exported to other regions or countries, and also recognises that the transportation of wastes can have significant environmental impacts. The principal aim of this waste strategy process is to conform with local, national and European waste policy.

6 Performance of Options

This section presents and discusses the performance of the waste management options against each of the indicators. For a full description of the indicators see chapter 5, table 45 and appendix 6. A summary of the overall performance of all options in terms of recycling, composting, energy recovery and landfill levels by stream is shown in table 10. A further breakdown of each option, broken down to Local Authority level, is shown in tables 11 – 27.

Environmental & Health Objectives

Objective 1: To ensure prudent use of land and other resources

Indicator 1(i): **Abiotic Resource Depletion of resources such as water, fuels and ores**
Method of measurement: WRATE output – a lower or more negative score is desirable

This indicator examines the amount of abiotic resources used to deliver each waste management option. It is part of the suite of standard life cycle indicators produced by WRATE and is presented using the unit "kg of antinomy equivalent". This means that the depletion of "non-living" mineral and metallic resources are characterised so that their depletion may be presented as an equivalent mass of antimony (see appendix 6 for details of WRATE impact assessments). A positive value from the WRATE model indicates that the option has resulted in the depletion of abiotic resources, a negative value represents an avoided burden.

- Best Option: 3D MBT followed by fuel to offsite energy use
- Worst Option: 4E Autoclave/MHT followed by Landfill

All options demonstrate a significant environmental saving; however, this is predominantly due to the high levels of recycling, particularly the recycling of Aluminium. The differences between the options can be attributed to differences in the method of residual treatment.

3D Scores well on this indicator as the off site energy plant used to treat the RDF following MBT has not been built specifically for the purpose of treating waste, therefore, the resource impacts associated with the construction of a residual waste treatment plant are significantly reduced.

The performance of all options for this indicator is shown in tables 46 and 63 and figure 26.

Indicator 1(ii): Land take
Method of measurement: Generic Data – A lower score is preferable

This indicator provides an estimation of the land required to deliver each of the waste management options. The indicator is calculated by multiplying the number of each facility type required (see tables 28-44) by an assumed land take per facility[13] (see table 51 – column 6)

- Best Option: 2A Pyrolysis
- Worst Option: 3F MBT followed by landfill

Options 2A and 2C require the least amount of land for waste facilities, as only one type of residual treatment facility is required. In contrast, option 2B requires a Dirty MRF prior to thermal treatment adding to the land take at the residual treatment plant and further land is required to provide the landfill to dispose of the rejects from the MRF. There are no significant outputs from the pyrolysis plant that require disposal.

Option 3F is the worst scoring option and this reflects the fact that an MBT treatment facility is required, as is considerable landfill space to receive rejects, the RDF fuel produced and the bio stabilised organic fraction.

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[13] This data is taken from the data collected in the WRATE model for each facility type

The land take impacts of re-processors or exempt facilities for C&D waste have not been considered in this indicator.

The performance of all options for this indicator is shown in tables 46 and 63 and figure 27.

Objective 2: To reduce greenhouse gas emissions

Indicator 2(i): Greenhouse gases emitted
Method of measurement: WRATE output – a lower or more negative score is preferable

This indicator quantifies the amount of gaseous emissions generated or avoided by the waste management system that are known to contribute to climate change. The indicator is part of the suite of standard life cycle indicators produced by WRATE and is presented using the unit "kg of carbon dioxide equivalent". This means that the total releases (or avoided releases) of all greenhouse gases are normalised such that their global warming potential is presented as an equivalent tonnage of CO_2. A positive value from the WRATE model indicates that the option has resulted in the production of gases contributing to global warming, and a negative value indicates that there has been a saving.

- Best Option: 3B MBT followed by Gasification
- Worst Option: 0 All residual waste to landfill

As with the resource depletion indicator, there is a large overall avoided burden in the generation of greenhouse gases but again, much of this is due to the recycling processes. The difference in performance between the options can be attributed to the residual waste treatment processes. In general, MBT combined with thermal recovery of RDF (options 3a – 3c) performed better in the avoidance of greenhouse gas production than just thermal recovery.

The performance of all options for this indicator is shown in tables 46 and 63 and figure 28.

Objective 3: To minimise adverse impacts on air quality and public health

Indicator 3(i): Emissions which are injurious to public health
Method of measurement: WRATE output – a lower or more negative score is preferable

This indicator quantifies the amount of gaseous emissions that are detrimental to human health and are either produced or avoided for each waste management option. It is part of the suite of standard life cycle indicators produced by WRATE and is presented using the unit "kg of 1,4-dichlorobenzene". This means that the total releases (or avoided releases) of gases deemed to be detrimental to human health are characterised such that their toxicity is presented as an equivalent mass of 1,4-dichlorobenzene. A positive value from the WRATE model indicates that the option has resulted in the production of gases, and a negative value indicates that the production of emissions injurious to human health has been avoided by the waste management system.

- Best Option: 4E Autoclave/MHT followed by Landfill
- Worst Option: 2C Incineration with energy recovery

This indicator score is derived from a range of gaseous emissions normalised to the toxic equivalence of 1,4-dochlorobenzene produced or avoided as a result of waste management activities. Option 2C performs least well, although all options result in avoided burdens. It should be noted that potential impacts on human health have a locational aspect and therefore this indicator can't determine actual exposure to these emissions. Health impact assessments on specific sites or choices of sites would be required to determine the actual predicted impacts.

Although there is some variation between the types of thermal treatment and their performance for this indicator, all of the facilities comply with the requirements of the WID Directive. The relative differences between all options are small, and each demonstrates the benefits of recycling in their overall scores.

The performance of all options for this indicator is shown in tables 46 and 63 and figure 29.

Indicator 3(ii): Emissions contributing to air acidification
Method of measurement: WRATE output – a lower or more negative score is preferable

This indicator quantifies the amount of emissions of acidifying compounds. These emissions are either produced or avoided by waste management operations within the model. The indicator is part of the suite of standard life cycle indicators produced by WRATE and is presented using the unit "kg of sulphur dioxide". This means that the total releases (or avoided releases) of gases contributing towards air acidification are characterised such that their acidifying potential is presented as an equivalent mass of SO_2. A positive value from the WRATE model indicates that the option has resulted in the production of gases causing air acidification, a negative value indicates that the process has avoided the emission of acidifying gases.

- Best Option: 4D Autoclave/MHT followed by fuel to off-site energy use
- Worst Option: 2C Incineration with energy recovery

There is some variance between the options for this indicator. Option 4D, where the residual waste is treated using an autoclave plant and the fibre is then sent to off site energy use, has the most negative value for this indicator. All of the autoclave options perform reasonably well. No burning takes place at the plant and thus gaseous emissions are avoided here. Also, metals are extracted for recycling which has an environmental benefit through the avoidance of energy used for metal production.

The performance of all options for this indicator is shown in tables 46 and 63 and figure 30.

Indicator 3(iii): Emissions contributing to depletion of the ozone layer
Method of measurement: WRATE output – a lower or more negative score is preferable

This indicator is calculated in WRATE's life cycle inventory and quantifies the amount of ozone depleting substances as "kg CFC-11 equivalent" produced or avoided as a result of the waste management system. This means that the total releases (or avoided releases) of gases contributing towards ozone depletion are characterised such that their depleting potential is presented as an equivalent mass of CFC-11.

- Best Option: 2C Incineration with energy recovery
- Worst Option: 0 All residual waste to landfill

Incinerator plants generally have very high tech flue gas cleaning systems where as landfills are quite poor at cleaning gases before they are released to the atmosphere. The incinerators are more efficient at removing chlorinated substances.

The performance of all options for this indicator is shown in tables 46 and 63 and figure 31.

Indicator 3(iv): Extent of odour problems
Method of measurement: Professional Judgement – a lower score is preferable

For this indicator each facility type was considered by the professional judgement panel and the odour scores in table 47 were derived (see appendix 6 for the derivation). Each score was then multiplied by the modelled number of facilities in each option (see tables 28-44 for infrastructure requirements).

- Best Option: 2A Pyrolysis
- Worst Option: 3E MBT with Anaerobic digestion

Option 3E and 2D performed badly as a significant amount of waste is delivered to an anaerobic digestion plant - a poor scoring facility type for odour relative to most other options. The options also result in a high percentage of waste being sent to landfill, which contributes to the odour score.

All residual waste in option 2A is delivered to the pyrolysis plant, which has a relatively low facility score for odour, and the outputs contribute little to odour problems. Bottom ash is sent for recycling and a small amount of Air Pollution Control Residue (fly ash) is sent to landfill. In general the options which included a two stage residual treatment technology (e.g. MBT followed by incineration) performed less well than those options where only a single stage technology was modelled (e.g. all waste direct to incineration).

The performance of all options for this indicator is shown in tables 52 and 63 and figure 32.

Indicator 3(v): Extent of dust problems
Method of measurement: Professional Judgement – a lower score is preferable

For this indicator each facility type was considered by the professional judgement panel and the dust scores in table 48 were derived (see appendix 6 for the derivation). Each score was then multiplied by the modelled number of facilities in each option (see tables 28-44 for infrastructure requirements).

- Best Option: 2C Incineration with energy recovery
- Worst Option: 2B Gasification

One component of the odour and dust indicators for each facility was vehicle movements. Waste is essentially double handled in option 2B, first as an input to the dirty MRF and gasification plant (this has a worse score than pyrolysis or incineration as pre-treatment is required) and then the reject fraction requires landfill disposal. This increases the expected number of vehicle movements and contributes towards the poor score for options where the same waste is handled at two different facilities.

For the best performing option, all residual waste in option 2C is delivered to an incinerator, which has a relatively low facility score for dust and no reject requiring subsequent management.

The performance of all options for this indicator is shown in tables 52 and 63 and figure 33.

3(vi) Indicator: Dioxin emissions
Method of measurement: WRATE output – a lower score is preferable

This indicator is calculated in WRATE's life cycle inventory and quantifies the amount of dioxins and furans produced or avoided as a result of the waste management system

- Best Option: 2D Anaerobic digestion
- Worst Option: 2C Incineration with energy recovery

All options resulted in the slight avoidance of dioxin emissions. The results do not differ significantly between options as is shown in figure 34. The difference between the best and worst performing options is just 0.00039 kg.

The performance of all options for this indicator is shown in tables 46 and 63 and figure 34.

Objective 4: To conserve landscapes and townscapes

Indicator 4(i): Extent of visual and landscape impacts
Method of measurement: Professional Judgement – a lower score is preferable

For this indicator each facility type was considered by the professional judgement panel and the visual and landscape scores in table 51 were derived (see appendix 6 for the derivation). Each score was then multiplied by the modelled number of facilities in each option (see tables 28-44 for infrastructure requirements).

- Best Option: 2A Pyrolysis
- Worst Option: 3E MBT with Anaerobic Digestion

The residual treatment method for option 2A is a one-stage process with no requirement for waste pre-treatment, no substantial process rejects and few outputs requiring disposal. As there is little double handling of waste, the land take and combined visual and landscape impacts are low.

Options 3E, 3F and 0 score poorly for this indicator primarily due to the amount of landfill disposal required. Option 3E has less landfill requirement than option 0; however, once more there is a cumulative effect of double handling the waste at a treatment facility and then a significant reject fraction also requiring disposal. The visual and landscape impacts of building an in-building facility to enable the MBT treatment to take place are added to the need to landfill a significant proportion of the outputs.

The performance of all options for this indicator is shown in tables 51, 54 and 63 and figure 35.

Objective 5: To protect local amenity

5(i) Indicator: Extent of noise, litter and vermin problems
Method of measurement: Professional Judgement – a lower score is preferable

For this indicator each facility type was considered by the professional judgement panel and the noise, litter and vermin scores in table 49 and 50 were derived (see appendix 6 for the derivation). Each score was then multiplied by the modelled number of facilities in each option (see tables 28 - 44 for infrastructure requirements).

- Best Option: 2C Incineration with Energy Recovery
- Worst Option: 3E MBT with Anaerobic Digestion

The clear dividing factor in how each option has scored for this indicator is whether the process includes a pre-treatment. For example, of the energy from waste technologies, options 2B, 3E and 3F perform less well for this indicator as there is a cumulative effect of first handling the waste at the pre-treatment stage and then a sizeable reject fraction is also sent to landfill. The single stage treatments in options 2A and 2C perform well for this indicator as the waste is delivered directly to one facility, the process is contained within building and no physical pre-treatment of the waste takes place.

The performance of all options for this indicator is shown in tables 49, 50, 53 and 63 and figure 36.

Objective 6: To minimise adverse effects on water quality

6(i) Indicator: Emissions contributing to eutrophication
Method of measurement: WRATE output – a lower score is preferable

This indicator is calculated in WRATE's life cycle inventory and quantifies the amount of “kg PO_4 equivalent” produced or avoided as a result of the waste management system. This means that the total releases (or avoided releases) contributing towards eutrophication are characterised such that their eutrophication potential is presented as an equivalent mass of phosphate.

- Best Option: 3B MBT with Gasification
- Worst Option: 3D MBT with Off-Site Energy Use

The MHT/Autoclave and MBT options performed well for this indicator although options where the fibre is sent for offsite energy use performed least well.

Further analysis of the potential impact for eutrophication of watercourses from cement kilns revealed that NOx emissions direct to air from the incinerator stack were dominant (circa 90%) (i.e through assumed deposition to water and subsequent nitrification in susceptible watercourses), followed by ammonia emissions to water (circa 10%).

For compilation of the cement kiln dataset in WRATE, NOx emissions were estimated from the pollution inventory for an operational cement kiln in 2004 and these were allocated to the RDF. These data are representative of a cement kiln with intermediate emissions abatement. Improved abatement systems such as selective non-catalytic reduction-DeNOx systems are likely to reduce such emission in future.

The performance of all options for this indicator is shown in tables 46, 63 and figure 37

6(ii) Indicator: Extent of water pollution
Method of measurement: WRATE output (aquatic ecotoxicity) – a lower score is preferable

This indicator is calculated in WRATE's life cycle inventory and quantifies the amount of releases contributing to aquatic ecotoxicity normalised as “kg 1,4-dichloro-benzene equivalent”. This means that the total releases (or avoided releases) contributing towards aquatic ecotoxicology are characterised such that their polluting potential is presented as an equivalent mass of 1,4-dichlorobenzene.

- Best Option: 3C MBT followed by incineration with energy recovery
- Worst Option: 0 All residual waste to landfill

Option 0 scores badly as leachate is produced at a landfill site and has the potential to contribute significantly to water pollution. Those technologies that include a waste pre-treatment and stabilisation perform better for this indicator than options where a single treatment takes place.

The performance of all options for this indicator is shown in tables 46 and 63 and figure 38.

Socio-Economic Objectives

Objective 7: To minimise local transport impacts

7(i) Indicator: Total waste kilometres
Method of measurement: Generic Data – a lower score is preferable

This indicator provides an estimation of the total waste kilometres travelled in order to deliver each of the waste management options. The indicator quantifies the cumulative distance travelled by all waste from the point of production to the first waste facility (either as a bulk collection or by car to CA site) including an account of the distance of the collection round. It also includes the distance travelled during all subsequent phases including long distance haulage to waste re-processors which may be outside the region.

- Best Option: 0 Landfill
- Worst Option: 4D Autoclave/MHT followed by fuel to offsite energy use

Option 0 results in the least waste mileage as all wastes are delivered to one facility. There are no waste treatment processes taking place and therefore no products or rejects require onward transport. The MHT/autoclave options generate a high mileage due to the substantial amounts of recyclate that are extracted, which require onward transportation to a re-processor (often outside of the North Wales area).

The options with offsite energy usage (3D and 4D) also perform poorly as the modelled distance is based on one site serving the entire region.

The performance of all options for this indicator can be found in tables 55 and 63 and figure 39.

7(ii) Indicator: Transport along roads other than motorways
Method of measurement: Generic Data – a lower score is preferable

This indicator provides an estimation of the waste kilometres travelled along non-motorway roads in order to deliver each of the waste management options.

- Best Option: 0 Landfill
- Worst Option: 3D MBT followed by fuel to offsite energy use

The pattern for this indicator is much the same as for total waste kilometres. 3D falls into last place as more RDF is sent to the cement kiln than fibre derived from the autoclave in option 4D. This transport is all within the region and, as there are no motorways in north Wales, all of this distance contributes to the non-motorway indicator. A larger proportion of the waste distance in 4D was made up by recyclable material transported to a re-processor which, if outside of the region, would involve some motorway transport.

The performance of all options for this indicator can be found in tables 56 and 63 and figure 40.

Objective 8: To provide employment opportunities

8(i) Indicator: Number of jobs likely to be created[14]
Method of measurement: Generic data - higher score preferable

Much of Wales has lower than average levels of employment due to structural changes that have happened to the industrial base over recent decades. The economic opportunities offered by waste processing can be viewed as beneficial.

This indicator provides an estimate of jobs required to directly staff each of the residual waste treatment facilities. For example this includes in option 2C the number of staff required to operate the incinerators, the hazardous landfill which receives the air pollution control residues and the inert and non-hazardous landfills receiving residual construction and demolition wastes. The number of jobs per facility was estimated using site specific information from reference plants in the Environment Agency's Waste Technology Data Centre.

- Best Option: 2B Gasification
- Worst Option: 1C Low levels of incineration with energy recovery

Option 2B is a gasification plant, which requires a front-end materials recovery facility. Both of these plants are labour intensive in comparison to all the other facilities and therefore create the most employment opportunities. Due to the high reject rate, there is also the need for staff to operate the landfill sites that receive the reject fraction. Option 1C involved a small amount of waste being treated through a one-stage process with little manpower requirement and the remainder being disposed at landfill. Landfill sites require less direct manpower in comparison to many treatment facilities, therefore option 0 also scores poorly on this indicator.

The performance of all options for this indicator can be found in tables 57 and 63 and figure 41.

Objective 9: To provide opportunities for public involvement and education

9(i) Indicator: Extent of opportunities for public involvement and education (concerning sustainable waste management practices)
Method of measurement: Professional Judgement - lower score preferable

Education on sustainable waste management is desirable, we all produce waste and we all need to understand what happens to the materials we discard and how those materials can contribute to the economy through recovery of materials or energy.

The professional judgement panel discussed a scoring system for this indicator and an amendment to the approach was proposed. There wasn't an obvious way of scoring one technology choice against the others to determine the possible extent of public involvement and education. As a proxy for this indicator, it was agreed that a single score on a scale of 1 to 10 would represent how the technology choice was perceived by the general public to have a potential for energy recovery.

- Best Option: 3D MBT followed by fuel to offsite energy use
- Worst Option: 0 All residual waste to landfill

[14] The typical number of employees per facility are taken from case studies on the Environment Agency Waste Technology Data Centre http://www.environment-agency.gov.uk/wtd

This indicator reflects the waste hierarchy, which scores landfill as the worst option.

The performance of all options for this indicator can be found in tables 58 and 63 and figure 42.

Waste Management Service Delivery Objectives

Objective 10: To minimise costs of waste management

10(i) Indicator: Costs of management and disposal, including material and energy revenues
Method of measurement: Generic Data – a lower score is preferable

Management of waste is a cost to society as a whole and needs to be kept to a minimum necessary to achieve environmentally acceptable outcomes.

The only facilities that were considered in the costing indicator were the residual treatment and disposal facilities. Following the methodology described in appendix 6, a “per tonne” cost for each residual treatment facility was derived. This included a combination of capital and operational costs and for new technologies is based on data provided by the Waste Technology Data Centre.

- Best Option: 0 All residual waste to landfill
- Worst Option: 3F MBT followed by Landfill

The landfill option scores well for this indicator reflecting the historical reliance on landfill as a cheap disposal option. As current treatment costs have been included for all other facilities, the current rate of landfill tax[15] has been included for waste landfilled. It is expected that landfill tax will have risen to £35 per tonne for active waste in 2013. Also not considered for this indicator is that for every tonne of MSW that a local authority disposes to landfill beyond the amount permitted under the Landfill Allowance Scheme Regulations (Wales) a fine of £200 would be levied by the Welsh Assembly Government. Options 1A and 1C also scored well as there is a requirement for few treatment facilities within these options.

In general, two stage processes carry a greater cost than single stage processes as, for example, in option 3C there is cost to build and operate the MBT facility and a further cost to build and operate the incinerator that receives the RDF.

The performance of all options for this indicator can be found in tables 59 and 63 and figure 43.

Objective 11: To ensure reliability of delivery

11(i) Indicator: Likelihood of implementation within required timescale, taking account of maturity of technology, necessary level of public participation, and the need for planning permission (taking account of scale of development and likely perceived adverse impacts)
Method of measurement: Professional Judgement - higher score preferable

The changes to the way we manage our waste, from landfilling the majority of municipal waste and a high proportion of other waste streams to a higher degree of recovery both of resources and energy, are urgently needed. Options that are more likely to be delivered within the required timescale are therefore more desirable. It is essential that waste management infrastructure is developed quickly in order to meet ever more challenging targets. The result of not developing the infrastructure will result in an over-reliance on landfill and the potential for substantial fines for non-compliance with legislation.

- Best Option: 0 All residual waste to landfill
- Worst Option: 4C Autoclave/MHT followed by incineration with energy recovery

[15] £21 per tonne for active waste and £2 per tonne for inert

Option 0 scores well on this indicator as there is little change from today's dominant waste management methodology (apart from increased recycling and composting in accord with all options) and therefore has the most likelihood of implementation by 2013. This is however not an option for the future as over-reliance on landfill is not sustainable.

Other options that scored well were those that included incineration with energy recovery, anaerobic digestion and MBT with off-site energy use. These are generally technologies that have a proven track record; in the case of off-site energy use, there is no need for additional infrastructure in addition to the MBT as it is assumed that existing facilities will be used.

Option 4C includes an autoclave, which is not a proven technology in this country, as well as the requirement of incinerators, which are likely to face public opposition at the planning stage due to current adverse perception of the technology amongst the public.

The performance of all options for this indicator can be found in tables 60 and 63 and figure 44.

Public Framework Objectives

Objective 12: **To conform with waste policy**

12(i) Indicator: Percentage composted
Method of measurement: Generic Data - higher score preferable

The Wales Waste Strategy places a high emphasis on composting. This is a mechanism whereby material that would otherwise generate methane in landfill sites can be turned into a resource.

- Best Option: All equal
- Worst Option: All equal

All options are the same for this indicator as all the composting is part of the front-end process.

The performance of all options for this indicator can be found in tables 61 and 63 and figure 46.

12(ii) Indicator: Percentage recycled
Method of measurement: Generic Data - higher score preferable

The Wales waste strategy places a high emphasis on recycling, this is a mechanism where resources can be retained within the economic cycle and is a major contributor to increasing sustainability overall. All resources are finite and conservation of resources is desirable, loss of resources into landfill is not a sustainable practice and should be minimised.

- Best Option: 2A Pyrolysis
- Worst Option: 0 All residual waste to landfill

Option 2A scores particularly well on this indicator is because it produces so much 'Incinerator bottom ash' which is sent direct to a recycling processor. Option 0 scores worst on this indicator as it contains only the front end recycling rates that are included in all the options as a minimum.

The performance of all options for this indicator can be found in tables 61 and 63 and figure 45.

12(iii) Indicator: Percentage landfilled
Method of measurement: Generic Data – a lower score is preferable

Policy at a Wales level is to reduce the amount of waste landfilled, this will comply with European policy and contribute to the improved sustainability of the nation through the retention of resources in the economy. The Welsh Assembly Government has a statutory driver in the Government of Wales Act 1998 to take account of sustainability.

- Best Option: 2A Pyrolysis
- Worst Option: 0 All residual waste to landfill

In options 2A and C, waste is recovered using either an incinerator or advanced thermal treatment plant without pre-treatment. This results in a minimum amount of waste requiring landfill disposal. Other options, which include some sort of mechanical or biological treatment, produce rejects which generally require disposal at landfill, so these divert less waste from landfill than options where waste is delivered directly to thermal treatment facility. Option 0 performs the worst for this indicator as all waste is landfilled following source-separated recycling/composting.

The performance of all options for this indicator can be found in tables 61 and 63 and figure 47.

7 Weighting of Sustainability Indicators

The weighting of the indicators is recommended by the ODPM guidance. This is because it is accepted that decision-makers are likely to attach more importance to some indicators or criteria than to others. The guidance shows that, by eliciting and applying 'weights' to the valued performance information, the relative importance of indicators can be taken into account.

All stakeholders including local authorities, government agencies and waste trade associations of the regional waste groups were given an opportunity to provide their weighting of the indicators to capture a variety of opinions and different perspectives. These included:

- Unitary Authorities and National Parks Authorities
- Welsh Assembly Government (WAG)
- Environment Agency Wales (EAW)
- Countryside Council for Wales (CCW)
- Community Recycling Network in Wales (CYLCH)
- Wales Environment Trust (WET)
- Wales Environment Services Association (WESA)
- Arena Network
- Confederation of British Industry (CBI)

Each organisation was given 22 points to divide between the 22 indicators, according to their perceived relative importance. These were used to determine the final weighting of the indicators for each of the regions.

The actual calculation of the weighting scores had to be agreed for each regional waste group. This is because it was noted, as in the creation of the first regional waste plan, that there are more Unitary Authorities compared to other organisations in the regional waste groups. This could give Unitary Authorities a bigger proportion of the vote compared to other organisations. Therefore analysis was completed to see what effect there is on the weighting scores when the Unitary Authorities are given a combined vote compared to when they are each given a vote. 'UA Equal' is where Unitary Authorities are given a combined average score and then averaged with the rest of the organisation scores. 'Average Weighting' is where Unitary Authorities are each given a score and averaged with the rest of the organisations.

The results showed that there were slight differences between the two calculation methods. With the 'UA Equal' method there was higher weighting given to the greenhouse gas emissions indicator for all regions and also in particular resource depletion in South West Wales. With the 'Average Weighting' method, costs of waste management and likelihood of implementation were weighted higher in South West and North Wales. Also, quantity of emissions injurious to human health indicator was weighted higher in South East and North Wales.

Following the analysis, It was agreed in North Wales to use the weighting scores from the 'UA Equal' method and in South East & South West Wales to use the 'Average Weighting' method of calculation. Table 65 shows the agreed weightings in the three regional waste groups in Wales. The results show that North Wales chose to use the UA Equal method.

The final weightings agreed for each of the regions, as shown in Table 65, are applied to the performance scores generated for the indicators. These are used to review the preferred strategic waste management option for all controlled wastes for each region.

8 Sensitivity Analysis

A sensitivity test was completed on the indicator weightings agreed by the North Wales Regional Waste Group. As each indicator in its raw form had different units and scales, the indicator scores had to be valued in order to enable comparison of the overall performance of each waste management option. This involved placing each indicator onto a scale of 0 to 1, where 0 represented the worst performing option for that specific indicator and 1 represented the best performing option.

This created a theoretical maximum valued[16] score for an option of 22, attainable if an option performs the best for each of the 22 SWMO indicators. The valued score results for both BPEO and SWMO can be found in table 64 and figures 48 and 51.

Following the weighting process detailed in chapter 7, each indicator had a weighting factor applied and the option scores were recalculated. The results of this are shown in table 66 and figures 49 and 52.

To examine the impacts of these weightings, they were reversed, and then re-applied to each valued indicator score and the option scores were again recalculated. The reverse weighted indicator scores can be found in table 67 and figures 50 and 53.

A summary of all rankings for BPEO and SWMO using valued, weighted and reverse weighted indicators are shown in table 68.

For BPEO indicators without weightings (figure 48), the top four options attained scores that were extremely close. When weightings were applied (figure 49), the top four options remained the same however, options 3B, 3D and 3A moved ahead of 2A as they scored higher against the greenhouse gas indicator (weighted 2.10) and for “extent of water pollution” (weighted 1.32). When the weights were reversed (figure 50) the order of the top four options reverted back to match the order for valued scores. This shows that for BPEO the weighting process did influence the ranking of the top four options, but as they were initially very close it is not surprising that the weightings would have had some impact.

For SWMO indicators the weighting had less impact on the overall outcome. 2A remains as the leading option for valued, weighted and reverse weighting of indicators (see figures 51-53); however by weighting the indicators there is less difference between the top performing 6 options. Reversing the weightings resulted in the difference between the best performing option and the 6th best option widening from 2.2 points to 4.5. With reverse weights, the pyrolysis option (2A) scored two points higher than any other option. 2A received good scores for the odour, dust and landtake indicators which, when combined with the high reverse weights for these indicators, scored exceptionally well.

A further sensitivity test was carried out on the WRATE derived indicators by altering the power generation mix to reflect the expected energy mix for Wales in 2020 as opposed to 2013. The energy mixes used for the main project and in the sensitivity test are shown in appendix 2 of part 3. The mix for 2020 has a lower reliance on coal, with greater use of renewable sources and gas. The purpose of the sensitivity test was to determine whether the energy mix in use would result in significant increases or decreases in the performance of any of the options.

Revised results were generated using the WRATE model, and were used to recalculate the SWMO scores for each option. The results of this exercise are shown in figure 55 (weighted indicators only). All of the scores altered very marginally, and there were no changes to the rankings of the top options.

[16] A valued score is the sum of the indicator scores before any weightings are applied

9 Summary

Review of Options

By using the methodology described, the different options can be compared against a number of different assessment criteria. This sustainability assessment has considered 5 main options with 17 sub-options for management of waste in 2013 (assessment year), the full list of options being:

Option 0
'Do Nothing' strategy
(This option is included for assessment purposes only – as a baseline to compare the other Options against). The same front-end levels of recycling and composting as the other options with no further treatment and all residual waste sent to landfill.

Option 1
A landfill-led strategy for residual waste
High recycling and composting levels followed by *low* levels of thermal treatment of residual waste using either:

- Pyrolysis (Option 1A), or
- Gasification (Option 1B), or
- Incineration with energy recovery (Option 1C)

All remaining residual waste would then be sent to landfill.

Option 2
An Energy from Waste-led strategy for residual waste
High recycling and composting levels with all remaining residual wastes, where possible, being treated by *high* levels of thermal treatment using either:

- Pyrolysis (Option 2A), or
- Gasification (Option 2B), or
- Incineration with energy recovery (Option 2C)
- Anaerobic digestion (Option 2D)

Any remaining residual waste would then be sent to landfill.

Option 3
An MBT/BMT-led strategy for residual waste
High recycling and composting levels, all remaining residual wastes being sent to MBT/BMT with the output recovered / disposed of using either:

- Pyrolysis (Option 3A), or
- Gasification (Option 3B), or
- Incineration with energy recovery (Option 3C), or
- Fuel to off-site energy use (Option 3D), or
- On-site Anaerobic digestion (Option 3E), or
- Landfill (Option 3F)

For Options 3A–3E, any remaining residual waste would then be sent to landfill.

Option 4
An autoclave/MHT-led strategy for residual waste
High recycling and composting levels, all remaining residual wastes being sent to autoclave with the output recovered / disposed of using either:

- Pyrolysis (Option 4A), or
- Gasification (Option 4B), or
- Incineration with energy recovery (Option 4C), or
- Fuel to off-site energy use (Option 4D), or
- Landfill (Option 4E)

For Options 4C to 4D, any remaining residual waste would then sent to landfill.

It was not possible to assess options 4A and 4B following guidance from the Environment Agency's LCA Advisor that the fibre produced would be unsuitable as a feedstock for advanced thermal treatment (pyrolysis/gasification).

Results: SWMO and BPEO for all options

Option 1: (A landfill-led strategy for residual waste)

Option 1a (Do minimum pyrolysis)

Weighted performance scores:	11th for weighted SWMO performance 12th for weighted BPEO performance
Valued performance scores[17]:	9th for SWMO valued performance 11th for BPEO valued performance
Sensitivity scores (Inverted criteria)[18]:	7th for SWMO weighted sensitivity 11th for BPEO weighted sensitivity

Option 1b (Do minimun gasification)

Weighted performance scores:	14th for weighted SWMO performance 15th for weighted BPEO performance
Valued performance scores:	14th for SWMO valued performance 14th for BPEO valued performance
Sensitivity scores (Inverted criteria):	15th for SWMO weighted sensitivity 15th for BPEO weighted sensitivity

Option 1c (Do minimum incineration with energy recovery)

Weighted performance scores:	12th for weighted SWMO performance 13th for weighted BPEO performance
Valued performance scores:	12th for SWMO valued performance 13th for BPEO valued performance
Sensitivity scores (Inverted criteria):	9th for SWMO weighted sensitivity 12th for BPEO weighted sensitivity

Option 2: (An Energy from Waste-led strategy for residual waste)

Option 2a (Pyrolysis of all residual waste)

Weighted performance scores:	1st for weighted SWMO performance 4th for weighted BPEO performance
Valued performance scores:	1st for SWMO valued performance 1st for BPEO valued performance
Sensitivity scores (Inverted criteria):	1st for SWMO weighted sensitivity 1st for BPEO weighted sensitivity

Option 2b (Gasification of all residual waste)

Weighted performance scores:	9th for weighted SWMO performance 11th for weighted BPEO performance
Valued performance scores:	11th for SWMO valued performance 12th for BPEO valued performance
Sensitivity scores (Inverted criteria):	13th for SWMO weighted sensitivity 13th for BPEO weighted sensitivity

[17] These are the sums of the raw valued scores before the weightings have been applied
[18] These are the results of reversing the weightings of the valued scores as a sensitivity test

Option 2c (Incineration with energy recovery of all residual waste)

Weighted performance scores: 5th for weighted SWMO performance
7th for weighted BPEO performance

Valued performance scores: 4th for SWMO valued performance
7th for BPEO valued performance

Sensitivity scores (Inverted criteria): 3rd for SWMO weighted sensitivity
5th for BPEO weighted sensitivity

Option 2d (Anaerobic digestion[19] of all residual waste)

Weighted performance scores: 10th for weighted SWMO performance
8th for weighted BPEO performance

Valued performance scores: 10th for SWMO valued performance
8th for BPEO valued performance

Sensitivity scores (Inverted criteria): 11th for SWMO weighted sensitivity
9th for BPEO weighted sensitivity

Option 3: (An MBT/BMT-led strategy for residual waste)

Option 3a (MBT of residual waste with RDF to pyrolysis)

Weighted performance scores: 3rd for weighted SWMO performance
3rd for weighted BPEO performance

Valued performance scores: 3rd for SWMO valued performance
4th for BPEO valued performance

Sensitivity scores (Inverted criteria): 4th for SWMO weighted sensitivity
4th for BPEO weighted sensitivity

Option 3b (MBT of residual waste with RDF to gasification)

Weighted performance scores: 2nd for weighted SWMO performance
1st for weighted BPEO performance

Valued performance scores: 2nd for SWMO valued performance
3rd for BPEO valued performance

Sensitivity scores (Inverted criteria): 2nd for SWMO weighted sensitivity
3rd for BPEO weighted sensitivity

Option 3c (MBT of residual waste with RDF to incineration with energy recovery)

Weighted performance scores: 6th for weighted SWMO performance
5th for weighted BPEO performance

Valued performance scores: 6th for SWMO valued performance
6th for BPEO valued performance

Sensitivity scores (Inverted criteria): 6th for SWMO weighted sensitivity
7th for BPEO weighted sensitivity

[19] This is modelled using an MBT process incorporating Anaerobic Digestion

Option 3d (MBT of residual waste with RDF to off-site energy use)

Weighted performance scores:	4th for weighted SWMO performance 2nd for weighted BPEO performance
Valued performance scores:	5th for SWMO valued performance 2nd for BPEO valued performance
Sensitivity scores (Inverted criteria):	5th for SWMO weighted sensitivity 2nd for BPEO weighted sensitivity

Option 3e (MBT/AD of residual waste with stabilite to landfill)

Weighted performance scores:	15th for weighted SWMO performance 14th for weighted BPEO performance
Valued performance scores:	16th for SWMO valued performance 16th for BPEO valued performance
Sensitivity scores (Inverted criteria):	16th for SWMO weighted sensitivity 16th for BPEO weighted sensitivity

Option 3f (MBT composting of residual waste with stabilite to landfill)

Weighted performance scores:	17th for weighted SWMO performance 16th for weighted BPEO performance
Valued performance scores:	17th for SWMO valued performance 17th for BPEO valued performance
Sensitivity scores (Inverted criteria):	17th for SWMO weighted sensitivity 17th for BPEO weighted sensitivity

Option 4: (An autoclave/MHT-led strategy for residual waste)

Option 4c (Autoclave/MHT of residual waste with fibre to incineration with energy recovery)

Weighted performance scores:	8th for weighted SWMO performance 9th for weighted BPEO performance
Valued performance scores:	8th for SWMO valued performance 9th for BPEO valued performance
Sensitivity scores(Inverted criteria):	10th for SWMO weighted sensitivity 8th for BPEO weighted sensitivity

Option 4d (Autoclave/MHT of residual waste with fibre to off-site fuel use)

Weighted performance scores:	7th for weighted SWMO performance 6th for weighted BPEO performance
Valued performance scores:	7th for SWMO valued performance 5th for BPEO valued performance
Sensitivity scores(Inverted criteria):	8th for SWMO weighted sensitivity 6th for BPEO weighted sensitivity

Option 4e (Autoclave/MHT of residual waste with fibre to landfill)

Weighted performance scores:	13th for weighted SWMO performance 10th for weighted BPEO performance
Valued performance scores:	13th for SWMO valued performance 10th for BPEO valued performance
Sensitivity scores(Inverted criteria):	14th for SWMO weighted sensitivity 10th for BPEO weighted sensitivity

Discussion of results

The best performing six options for SWMO and the top five for BPEO are from either option 2 or option 3 (see table 69), indicating that the broad strategy of thermally treating the residual waste with energy recovery, either directly or using a Mechanical and Biological pre-treatment, perform consistently well. Option 4D, where all residual waste is treated in an autoclave/MHT with the production of a feedstock for use off-site (for instance in a cement kiln) also performed well, ranking 6^{th} on weighted BPEO indicators and 7^{th} on weighted SWMO indicators.

Using BPEO criteria options 3B and 3D score highly. These option describe scenarios where all residual waste is treated at an MBT plant producing a Refuse Derived Fuel (RDF), material is extracted for recycling and the reject fraction is sent to landfill. The RDF is subsequently either treated by gasification (3B) or sent off-site for thermal treatment at an existing facility (3D).

Option 3B scored very well for a number of the BPEO indicators, including global warming potential and the eutrophication indicators, for which it was the best performing option. It also scored well for the percentage of waste landfilled, potential for water pollution and the potential to deplete the ozone layer. It should be noted that gasification technology is not proven in the treatment of municipal waste in the UK and there may therefore be issues of bankability to overcome.

It is perhaps not surprising that an option that includes a facility that is already in existence (3D) should score well. From an environmental perspective, the burdens are much less than for building a new facility, visual and landscape indicators score well as the facility is already in existence. The burning of the waste directly offsets the burning of coal in the cement kiln at a ratio of 1 tonne of waste offsetting 900 kg of coal. This differs from the benefits of burning waste in an energy from waste plant as this offsets the marginal mix of power generation options assumed for Wales in 2013, (see part 3 appendix 2) and is subject to the conversion efficiency of the thermal treatment plant.

Caution must be exercised in relation to use of RDF as a feedstock for an existing facility, as the likely constraint in the delivery of the option is the availability of capacity of suitable sites to receive the material. The model indicates a required capacity of over 300,000 tonnes per annum and it will be very difficult to secure this capacity either within the region or further afield.

The cement kiln option score less well when other sustainability criteria are included. For SWMO, the best performing option for valued, weighted and reverse weighted scores is option 2A. This is where all residual waste is sent to a pyrolysis plant.

The high ranking of option 2A may be due to the technology plant used in WRATE. The modelling is based upon the WasteGen Pyrolysis plant in Bergau, Germany. Efficiency and emissions standards in Germany are higher than in some other European countries so its overall performance may be better than other technologies based in UK. For example, the Coventry and Grimsby incinerators (upon which options 1C, 2C, 3C and 4C are based) comply with the standards set in the UK, but they may not meet the more stringent German standards. There are examples of substantially more efficient incinerators operational in mainland Europe.

Pyrolysis and gasification plants do not have an established history of treating municipal waste in the UK, neither does RDF to off site energy sites such as cement kilns. Therefore, options 2C and 3C may look like more attractive and more deliverable options in this regard.

The characterisation of options and the subsequent options assessment is based on assumed generic facility capacities, shown in Table 1 of this report. Some discrimination between the size of facility appropriate to rural and urban areas has been built into the modelling exercise. However, in reality, facilities are unlikely to conform to these assumed sizes; actual built capacities will depend very much on local factors. The impact of facility size on the performance of options does not form part of this assessment, but it is likely that larger facilities would perform slightly better than smaller facilities in overall terms. Whilst this may be the case, it does not eliminate the need for the appropriate use of smaller community based facilities which often form a fundamental part of an integrated strategy for waste management.

Option 0 was included for comparison purposes and does not score well. This reflects the situation whereby all residual waste is landfilled. In addition to the poor performance of the option using life cycle analysis and sustainability appraisal, this option is not suitable for Municipal Waste due to the requirement of the Landfill Directive to divert biodegradable waste from landfill.

Option 1 (do minimum thermal treatment) performs less well than option 2 (energy from waste-led strategy) indicating that it is most desirable to replace all landfill disposal with energy recovery rather than a partial replacement.

Option 4 relies on a technology that is commercially unproven for municipal waste in the UK. The option for using this technology followed by use of the RDF in an off-site facility such as a cement kiln was ranked 7th overall for weighted SWMO scores. Caution should be taken when relying on existing facilities to receive the RDF as there may be restricted capacity among such users to use the fuel. There is also some debate surrounding the quality of recyclates that can be recovered from facilities of these types.

Figure 52 illustrates the relative weighted scores of each option for SWMO criteria.

Diversion of Biodegradable Municipal Waste from landfill

A separate modelling exercise for Municipal Solid Waste (MSW) only was conducted using the WRATE tool. The aim was to assess the amount of biodegradable waste landfilled to enable comparison with the expected 2020 BMW allowances made under the Landfill Allowances scheme. WRATE calculates the amount of biodegradable waste landfilled based on assumed biodegradability of each fraction of waste that is managed.

The indications from this exercise, shown in table 62, are that all options apart from option 0, 1B, 2B, 2D, 3E, 3F and 4E deliver 2020 Landfill Allowance Scheme targets by 2013. Options 1B and 2B required the use of a Dirty MRF to produce a Refuse Derived Fuel for gasification. The rejects from the MRF process required disposal to landfill and contributed strongly to the amount of biodegradable waste landfilled. A number of MRF facilities from the model were tried and in each case the landfill allowance target was breached.

Options 2D and 3E are both MBT processes, which include Anaerobic Digestion. In option 2D, the process was based on a technology that operates from Australia where the regulatory regime allows the outputs from MBT to be applied to land as a soil improver. Environment Agency guidance restricts the usage of composts derived for mixed waste and so the low grade compost produced was modelled to landfill. A similar process operated in option 3E but this was based upon generic process data held in WRATE (see Appendix 3 of part 3 for an explanation of generic processes). The configuration was such that the MBT process also produced a Refuse Derived Fuel. As this option had no thermal treatment plant to burn the RDF, this was also landfilled.

Option 3F used a generic MBT process from WRATE (composting and RDF production) and, as with option 3E, the RDF produced as part of the process had no management route other than to landfill.

Option 4E used an autoclave to produce a fibre from the organic elements. The model suggests that a market needs to be found for the fibre as by using the process as a pre-treatment to landfill would be insufficient to meet 2020 landfill targets for North Wales in 2013.

These outcomes should be viewed with caution, as a number of factors would influence whether or not an authority met its LAS targets. A number of assumptions have been made about the composition of the waste, the types of material removed for recycling/composting and the amount of waste in the study year (a growth scenario of 3% pa was applied for Municipal Waste).

The actual reduction of biodegradability caused by a process also requires extensive monitoring and would be likely to vary dependent on the input composition. The performance of the facilities in WRATE is based on actual measurement of plant performance but this will also depend on the nature of the waste inputted. To demonstrate the actual reduction in biodegradability from a waste treatment plant, Environment Agency guidance must be adhered to.

Conclusions and recommendations

As several of the higher scoring options performed similarly, it is not possible to single out any one option as the Environment Agency's recommended strategy. However, it is important to point out some similarities between the better performing options. The best performing 6 options for SWMO criteria all fall within either option 2 or 3. Therefore, this study shows that Option 2: (An Energy from Waste-led strategy for residual waste) and Option 3: (An MBT/BMT-led strategy for residual waste) are broadly speaking the better-suited residual waste treatment options for North Wales. The option ranked 7th following weighting of the SWMO criteria was the autoclave/MHT option followed by use of the RDF in an off-site facility such as a cement kiln.

There are a number of exceptions to this rule. Option 2B did not score as well due to the high amount of reject from the dirty MRF process that is required to produce RDF prior to gasification. Options 2D, 3E and 3F are all MBT processes with no thermal treatment and do not perform well due to the fact that the waste is treated extensively but nonetheless much is eventually landfilled.

The results of sensitivity analyses broadly support these conclusions.

The Environment Agency's recommendation from this sustainability appraisal is that the higher performing options outlined above should form a technical basis for reviewing the Regional Waste Plan for North Wales. This allows for some flexibility in the option finally chosen, but gives broad guidelines as to the types of facilities that should be considered.

The results of these studies will be used to inform the North Wales Regional Waste Planning Group when they choose their preferred option for the Waste Plan Review but will not be used in isolation. It should be noted that a number of other studies are also to be carried out, including Health Impact Assessment and Strategic Environmental Assessment, and a full public consultation process will be undertaken before a preferred option can be incorporated into the plan.

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